Trends in Pediatric Adjusted Shock Index Predict Morbidity in Children with Moderate Blunt Injuries

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DISCLAIMERS: All authors have no conflicts of interest to disclose.

FUNDING: There is no funding for this paper.

AUTHOR CONTRIBUTION:
Study Conception and Design: Robert Vandewalle
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Analysis and Data Interpretation: Robert Vandewalle
Drafting of the Manuscript: Robert Vandewalle
Critical Revision: Robert Vandewalle, Julia Peceny, Jodi Raymond, Thomas Rouse

TYPE OF STUDY: Prognostic
LEVEL OF EVIDENCE: Level II

This is the author's manuscript of the article published in final edited form as:

Vandewalle, R. J., Peceny, J. K., Raymond, J. L., & Rouse, T. M. (2019). Trends in pediatric-adjusted shock index predict morbidity in children with moderate blunt injuries. Pediatric Surgery International, 35(7), 785–791. https://doi.org/10.1007/s00383-019-04469-2

ABSTRACT:

PURPOSE: Trending the pediatric-adjusted shock index (SIPA) after admission has been described for children suffering severe blunt injuries (i.e. injury severity score (ISS)≥15). We propose that following SIPA in children with moderate blunt injuries, as defined by ISS 10-14, has similar utility.

METHODS: The trauma registry at a single institution was queried over a seven year period. Patients were included if they were between 4-16 years old at the time of admission, sustained a blunt injury with an ISS 10-14, and were admitted less than 12 hours after their injury (n=501). Each patient's SIPA was then calculated at 0, 12, 24, 36, and 48 hours (h) after admission and then categorized as elevated or normal at each time frame based upon previously reported values. Trends in outcome variables as a function of time from admission for patients with an abnormal SIPA to normalize as well as patients with a normal admission SIPA to abnormal were analyzed.

RESULTS: In patients with a normal SIPA at arrival, elevation within the first 24h of admission correlated with increased length of stay (LOS). Increased transfusion requirement, incidence of infectious complications, and need for in-patient rehabilitation were also seen in analyzed sub-groups. An elevated SIPA at arrival with increased length of time to normalize SIPA correlated with increased length of stay LOS in the entire cohort and in those without head injury, but not in patients with a head injury. No deaths occurred within the study cohort.

CONCLUSIONS: Patients with an ISS 10-14 and a normal SIPA at time of arrival who then have an elevated SIPA in the first 24h of admission are at increased risk for morbidity including longer LOS and infectious complications. Similarly, time to normalize an elevated admission SIPA appears to directly correlate with LOS in patients without head injuries. No correlations with markers for morbidity could be identified in patients with a head injury and an elevated SIPA at arrival. This may be due to small sample size, as there were no relations to severity of head injury as measured by Head Abbreviated Injury Scale (Head AIS) and the outcome variables reported. This is an area of ongoing analysis. This study extends the previously reported utility of following SIPA after admission into milder blunt injuries

KEYWORDS: Pediatric, SIPA, Shock Index, Trauma, Injury

INTRODUCTION

The shock index (SI), defined as heart rate (HR: beats per minute) divided by systolic blood pressure (SBP: in mmHg) was initially described by Allgower and Buri in 1967 [1]. Within the adult population a normal SI ranges from 0.5-0.7 and a SI $\geq$0.9 has been considered a "break point" for increased severity of illness [2-4]. Application of SI within the pediatric trauma population is difficult secondary to differences in HR and SBP in children as a function of age. Within the last five years, Acker et al. have defined pediatric-adjusted SI (SIPA) values for children based upon vital signs across accepted age ranges and validated this model as a predictor for injury severity in blunt trauma [5]. Subsequent research has found SIPA useful in identification of severe head injury, identification of severe isolated blunt liver/spleen injury, need for trauma team activation, and need for abdominal CT after blunt trauma injury [6-10]. The most recent research has validated SIPA utilizing the Pediatric Trauma Quality Improvement Program (TQIP) database across a more diverse pediatric trauma population and as a triage tool for intensive care unit admission after isolated high grade solid organ injury [9, 11]. Cutoff values for SIPA are as follows: 1.22 (ages 4-6 years), 1.0 (ages 7-12), and 0.9 (ages 13-16) with values above these cutoffs considered abnormal.

Previous research from our institution suggests that following SIPA after admission serves as a prognostic tool for multiple indices of morbidity and mortality in pediatric patients with severe blunt injury [12]. This study utilized a cohort of patients that mirrored those reported by Acker et al. [5]. However, a more recent study has shown that SIPA has utility for patients beyond this study's criteria (i.e. age, injury severity, and injury mechanism) [11]. Because SIPA may have utility in patients beyond those in which it was initially described, we hypothesize that trends in SIPA will have value as a prognostic tool for patients with moderate blunt injury (i.e. Injury Severity Score (ISS) 10-14).

METHODS

In evaluating this cohort, the inclusion/exclusion criteria created by Acker et al. and used in a previous study evaluating trends in SIPA were utilized with the exception that only patients with an

ISS 10-14 were included [5, 12]. The trauma registry from a single institution (Riley Hospital for Children at IU Health, Indianapolis, Indiana) was queried for all patients sustaining blunt injuries with an ISS of 10-14 from January 1, 2010 to December 31, 2016. Internal Review Board (IRB) approval as well as waiver of consent was obtained from Indiana University for this retrospective review. Children were excluded from the study cohort if they were less than 4 years old or greater than 16 years old. While measuring SIPA at arrival in children less than 4 years of age has been shown to be valid, we chose to keep this age restriction to better parallel work previously completed at our institution [11, 12]. Additionally, patients were excluded if they presented to our institution more than 12 hours (h) after injury. Among the 501 patients identified, 338 (67.5%) were transferred from another institution. Among these patients, 227 (84.9%) presented to our institution within six hours of their time of injury. No patient presented more than nine hours after their injury. SIPA values were calculated for each patient at the time of arrival and every 12h thereafter until 48h after admission. These scores were then categorized as either “elevated” (i.e. above normal SIPA score for age range) or normal. Additionally, outcome variables related to SIPA previously reported by Acker et al. were reviewed along with demographic data (see table 1) [5]. Measured outcome variables included: Intensive Care Unit (ICU) length of stay (LOS), total hospital LOS, total days on mechanical ventilation, discharge to rehabilitation, blood transfusion within the first 24h of admission, in-hospital mortality, and infectious complications (i.e. ventilator-associated pneumonia (VAP), urinary tract infection (UTI), surgical site infection (SSI), and a composite of any of these infections). Time variables were measured in half-day intervals based upon the time of arrival to the emergency room. Patients were then categorized into two groups based upon their SIPA score at admission (i.e. elevated or not elevated). During the course of data analysis, it was noted that those patients without an elevation in SIPA at arrival had higher Head Abbreviated Injury Scale (Head AIS) than those who did. Therefore, sub-group analysis of shock index values for those with and without head injuries was completed within each of these two groups and outcomes were measured as a function of Head AIS in a similar fashion. Trends for outcomes for all groups at each subsequent 12-hour time interval based upon the presence or absence of an elevated SIPA were compiled. Chi-squared

analysis and Kruskal-Wallis tests were performed where appropriate with a p-value <0.05 considered statistically significant. Statistical analysis was completed utilizing Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 25 for Windows. When a variable was identified as statistically significant but median variables were the same, averages (i.e. means) reported.

RESULTS

Demographics

During the study period, 501 patients were identified that met inclusion/exclusion criteria (table 1). Within this cohort, 95 (19.0%) patients presented with an elevated SIPA and 406 (81.0%) did not. Analysis of patient demographics revealed a significant difference in gender (46.3% vs. 32.2% female), and Head AIS (0 vs. 2) for patients who had an elevated SIPA at arrival and those that did not, respectively (see table 1). There was no difference in these groups with respect to age and ISS. Analysis of outcome variables revealed a difference in LOS (2.6 vs. 2.0 days), total days on ventilator (0.4 vs. 0.2 days), need for transfusion within 24h of arrival (8.4% vs. 2.0%), and incidence of SSI (1.1% vs. 0%) for patients who had an elevated SIPA at arrival and those that did not, respectively (see table 1). There was no difference ICU LOS, discharge to rehabilitation, mortality, incidence of VAP, UTI, bacteremia, and composite infectious complications. Of note, no deaths occurred in the study cohort. **TABLE 1**

Review of All Patients with ISS 10-14

Among patients with an elevated SIPA at the time of arrival (n=95), there was a significant trend in LOS as time to normalize SIPA increased (see table 2). Additionally, there was an increased incidence in SSI and composite infectious complications as time to normalize SIPA increased. Upon review of patients with a normal SIPA at arrival (n=406), elevations in SIPA within the first 24h of admission were associated with increased length of stay, need for transfusion within

the first 24h of arrival, incidence of UTI and composite infectious complications (see table 3). Discharge to rehabilitation approached but did not reach statistical significance. **TABLES 2&3**

Review of Patients with ISS 10-14 and without Head Injury

Among patients with an elevated SIPA at the time of arrival without an associated head injury (n=54), there was a significant trend in LOS as time to normalize SIPA increased (see table 4). There was also an increased incidence in composite infectious complications as time to normalize SIPA increased. For patients with a normal SIPA at arrival without a head injury (n=167), elevations in SIPA within the first 24h of admission were associated with increased length of stay and incidence of composite infectious complications (see table 5). **TABLES 4&5**

Review of Patients with ISS 10-14 and with Head Injury

Among patients with an elevated SIPA at the time of arrival with an associated head injury (n=41), there was not a significant trend in LOS and time to normalize SIPA or incidence in composite infectious complications (see table 6). For patients with a normal SIPA at arrival with a head injury (n=239), elevations in SIPA within the first 24h of admission were associated with increased length of stay and days on ventilator. There was also in increased incidence of UTI, composite infectious complications, and discharge to inpatient rehabilitation (see table 7). The need for transfusion in the first 24h of arrival approached but did not reach statistical significance. **TABLES 6&7**

Review of Head AIS as a prognostic indicator

The study cohort was then analyzed for differences in the outcomes previously mentioned as a function of Head AIS (see table 8). When comparing all patients with a head injury to those who did not, there was a significant difference in ISS (11.3 vs. 10.8), incidence of elevated SIPA at arrival (14.6% vs. 24.4%), LOS (3.8 vs. 3.5 days), ICU LOS (1.0 vs. 0.3 days), and days on the ventilator (0.4 vs. 0.1 days) for patients with a head injury versus those without, respectively. Sub-group analysis revealed a significant difference in need for transfusion (12.2% vs. 1.7%), LOS (2.8 vs. 2.0

days) and days on the ventilator (0.6 vs. 0.3 days) for those patients with a head injury who presented with an elevated SIPA versus those that did not (see table 9). Further sub-group analysis did not find any correlation for severity of Head AIS and reported outcome variables when comparing all head injuries to non-head injury patients as well as in comparing head injured patients with or without SIPA elevation at the time of arrival (data not reported).

DISCUSSION

The purpose of this study was to determine if trending SIPA in a pediatric patient population with moderate blunt injury, as measured by ISS, has utility in predicting morbidity and/or mortality. Feasibility of this study was based upon work previous work completed at our institution as well as a recent multi-institutional collaboration that validated the shock index across a broad spectrum of pediatric trauma patients [11, 12]. Indeed, when comparing patients within our study cohort with an elevated SIPA at arrival to those who did not, there were multiple markers of increased morbidity. These markers included increased LOS, total ventilator days, need for transfusion in the first 24h of arrival and SSI. While this study is does not encompass the breadth or the number of patients analyzed by Nordin et al., these findings corroborate the use of SIPA beyond the patient population in which it was initially described [5, 11].

Within this study, two groups of patients were analyzed; those that had an elevated SIPA upon arrival and those that did not but possibly developed an elevated SIPA within 48h of admission, with concentration on elevation of SIPA within the first 24h of admission based upon findings from our previous study. The trends in SIPA either normalizing from an initial abnormal value or becoming abnormal when initially normal were analyzed. Unfortunately, within the data available to review and the overall low incidence of blood transfusion, our study was unable to correlate volume of initial blood transfusion with incidence/severity of SIPA elevation (data not reported). These results are similar to those found in our previous study [12]. Upon review of patient demographics, it was noted that those children who presented with an elevated SIPA had a lower Head AIS than those that did not. Given this finding, we chose to perform sub-group analysis dividing the

elevated/non-elevated SIPA patients further into those that had a head injury (i.e. Head AIS > 0) and those that did not (Head AIS = 0) and perform sub-group analysis. Similar to our previous report, monitoring HR or systolic blood pressure alone against the variables mentioned above did not show significant trends and/or was not specific for the metrics evaluated (data not reported).

Among patients with an elevated SIPA at arrival, the time to normalize SIPA had direct relation to total LOS when analyzing the entire study cohort. This is a similar trend to our previous study in children with severe blunt trauma [12]. This direct relation of increased LOS was also seen in sub-group analysis in patients without head injuries, but not in those patients with a head injury. The loss of statistical significance within this subgroup is not completely understood but may be due to the small sample size of patients with a head injury who also had an elevated SIPA at arrival. This group represented only 8.2% of the entire study cohort and 14.6% of patients with head injuries. As a result of this small sample, several time intervals analyzed had 6 or fewer patients, which limits the ability to analyze trends. Another possibility is that patients with head injuries and an ISS 10-14 do not follow the same trends with regards to SIPA as others within the study and those who have been previously reported. In order to determine if the presence of a head injury was correlated with outcome variables independent of SIPA, all patients with a head injury were compared to those without regardless of their SIPA at arrival. This analysis suggests that patients with a head injury had a higher ISS, longer LOS/ICU LOS/days on ventilator, and were less likely to have an elevated SIPA at arrival. While the lower incidence of an elevated SIPA in the setting of multiple markers of increased morbidity appears counter-intuitive a possible but unproven reason may be the associated hypertension seen in patients with head injuries, which could alter SIPA. Similarly, when comparing all patients with a head injury and elevated SIPA at arrival to patients with a head injury and a normal SIPA at arrival, patients with an elevated SIPA had an increased need for early transfusion, LOS and days on the ventilator. The finding of patients with a head injury and an elevated SIPA fairing worse with regard to the reported outcome variables is consistent with data reported by Acker et al. [7]. However, there was no identified trend in with increasing Head AIS and increased markers of morbidity. Recognizing the limitations of the study cohort sample size, these combined analyses

suggest that while head injury in the presence of an elevated SIPA has increased morbidity, increasing head injury does not predict outcome markers like those seen in the other cohorts with respect to trends in SIPA. Indeed, further analysis is warranted. Across all analyzed cohorts of patients with a normal SIPA at arrival, elevation of SIPA within 24h of arrival correlated with increased LOS. While the head injured cohort did have a statistically different ISS, the overall clinical difference may be negligible (i.e. ISS mean 11.3 vs. 10.8).

In addition, several other markers for morbidity were noted in patients with a normal SIPA at arrival who then developed an elevated SIPA after admission. Similar to our previous study this was most pronounced if SIPA elevated in the first 24h after admission [12]. Markers for morbidity in these groups included increased days on the ventilator, transfusion requirements, infectious complications, and need for rehabilitation after discharge. Of note, none of the infectious diagnoses were made during the initial 48h after admission, suggesting that trends in SIPA may reflect physiologic stress and subsequent predisposition to infection. Indeed, all infectious complications were diagnosed at least 48h after the study “window”. Trending SIPA to identify infectious complications early may serve as an additional utility for this metric but may be a confounding variable in the alterations in SIPA in some patients if infection contributes to tachycardia and/or hypotension.

Our study is not without limitation. Due to the retrospective nature of this study, only correlations between trends in shock index and the measured outcome variables can be made. An additional weakness of our study was the inability to determine why patients with head injuries and an elevated SIPA at arrival do not follow the trends seen in other studied groups. While we believe this is most likely a result of small sample size, this cannot be confirmed. However, within the constraints of this study, the severity of the head injury as measured by Head AIS (with or without an elevated SIPA at arrival) did not correlate with increased morbidity. Taken together with the fact that head injured patients with an elevated SIPA at arrival had higher indices for morbidity compared to those that did not suggests that sample size is a possible cause for this discrepancy. An area of

focus at our institution following this study will be to apply this study design against a broader cohort of patients with respect to ISS and Head AIS.

In a manner similar to our previous study, sample size across the study period prohibited further in-depth analysis of SIPA within the specific age ranges and a larger study would allow analysis within the three age ranges. Results of this study suggest that following SIPA beyond hospital admission serves as an additional marker for injury and helps with prognostication early in the hospital course among patients with an ISS 10-14, with the exception that patients with head injuries and an elevated SIPA at arrival may not follow these trends, although these patients fair worse than those with a normal SIPA at arrival.

The ultimate goal of this research would be to determine if following SIPA after admission will assist in patient care. Within our institution, utilization of SIPA to help determine level of admission (i.e. observation/floor admission/ICU admission) is being developed based upon prior publications [7, 9]. Within that construct, questions arose regarding what other utilities SIPA could have within this population after admission. This study, along with prior work at our institution, is serving as the framework for these additional treatment recommendations. An additional question that has resulted from this study was if infectious complications have been the source of longer LOS in some patients. Within the study population, treatment changes currently being considered include:

-Any patient with alterations in SIPA at arrival or within 24 hours of admission undergoes complete blood count (CBC)/urinalysis (UA) at 48 hours of admission unless clinical picture warrants earlier analysis. A chest x-ray is included at this time point for any patient with mechanical ventilation of any duration during the first 48 hours of admission.

-Patients with head injuries and an ISS 10-14 will be sent to the ICU for at least 24 hours and can be transitioned to a floor bed if there are no alterations in SIPA within this time period based upon clinical status. No recommendations can be made in children with head injuries and an elevated SIPA at arrival at this time.

These recommendations are based upon the assumption that pain and anemia have been adequately treated and are part of a larger set of recommendations for children with higher ISS. Ultimately the validation of these interventions will be assessed through an institutional quality improvement project monitoring LOS, early detection of infectious complications and resource over/under-utilization (i.e. un-needed ICU admissions, emergent floor-to-ICU transfers, etc.). While these measures will be based upon using SIPA to help direct patient care, this has yet to be validated. Additional interventions (i.e. transfusions, liberal crystalloid infusions, and/or pressors) to correct an abnormal SIPA are also being considered.

The goal of future research may include determining if the magnitude of elevation in SIPA correlates with outcomes, resuscitation metrics, and indices of ongoing bleeding. This will require multi-institutional collaboration and should be the next step in determining if there is additional value in following SIPA after admission beyond prognosis.

CONCLUSION

Patients with a normal SIPA at time of arrival who then have an elevated SIPA in the first 24h of admission are at increased risk for morbidity 48h of admission for patients with an ISS 10-14 regardless of the presence of a head injury including LOS and infectious complications. Similarly, time to normalize an elevated admission SIPA appears to directly correlate with LOS in patients without head injuries in children with moderate blunt injuries. However no correlations with the reported markers for morbidity could be identified in patients with a head injury and an elevated SIPA at arrival. This lack of correlation may be due to small sample size, as there were no relations to severity of head injury, as measured by Head AIS, and the outcome variables reported. This subset of patients is an area of ongoing analysis. Overall, this study compliments previous work at our institution for following SIPA after admission in pediatric blunt trauma.

Compliance with Ethical Standards

Funding: This study was not funded.

Conflict of Interest: Robert Vandewalle declares that he has no conflict of interest. Julia Peceny declares that she has no conflict of interest. Jodi Raymond declares that she has no conflict of interest. Thomas Rouse declares that he has no conflict of interest.

Ethical approval: This article does not contain any studies with human participants performed by any of the authors.

Informed consent: Waiver of consent was obtained prior to the initiation of this study by the Indiana University School of Medicine Institutional Review Board.

GLOSSARY OF ABBREVIATIONS

CBC: Complete Blood Count

CT: Computed Tomography

Head AIS: Abbreviated Injury Scale

HR: Heart Rate

ICU: Intensive Care Unit

IRB: Internal Review Board

ISS: Injury Severity Score

LOS: Length of Stay

SI: Shock Index

SIPA: Pediatric-Adjusted Shock Index

SSI: Surgical Site Infection

UA: Urinalysis

UTI: Urinary Tract Infection

VAP: Ventilator-Associated Pneumonia

REFERENCES

1. Allgower M, Burri C: ["Shock index"]. *Deutsche medizinische Wochenschrift* 1967, 92(43):1947-1950.
2. Oestern HJ, Trentz O, Hempelmann G, Trentz OA, Sturm J: Cardiorespiratory and metabolic patterns in multiple trauma patients. *Resuscitation* 1979, 7(3-4):169-183.
3. Rady MY, Nightingale P, Little RA, Edwards JD: Shock index: a re-evaluation in acute circulatory failure. *Resuscitation* 1992, 23(3):227-234.
4. Rady MY, Smithline HA, Blake H, Nowak R, Rivers E: A comparison of the shock index and conventional vital signs to identify acute, critical illness in the emergency department. *Annals of emergency medicine* 1994, 24(4):685-690.
5. Acker SN, Ross JT, Partrick DA, Tong S, Bensard DD: Pediatric specific shock index accurately identifies severely injured children. *J Pediatr Surg* 2015, 50(2):331-334.
6. Acker SN, Bredbeck B, Partrick DA, Kulungowski AM, Barnett CC, Bensard DD: Shock index, pediatric age-adjusted (SIPA) is more accurate than age-adjusted hypotension for trauma team activation. *Surgery* 2017, 161(3):803-807.
7. Acker SN, Ross JT, Partrick DA, Bensard DD: A pediatric specific shock index in combination with GMS identifies children with life threatening or severe traumatic brain injury. *Pediatr Surg Int* 2015, 31(11):1041-1046.
8. Acker SN, Stewart CL, Roosevelt GE, Partrick DA, Moore EE, Bensard DD: When is it safe to forgo abdominal CT in blunt-injured children? *Surgery* 2015, 158(2):408-412.
9. Arbuthnot M, Armstrong LB, Mooney DP: Can we safely decrease intensive care unit admissions for children with high grade isolated solid organ injuries? Using the shock index, pediatric age-adjusted and hematocrit to modify APSA admission guidelines. *J Pediatr Surg* 2017.
10. Linnaus ME, Notrica DM, Langlais CS, St Peter SD, Leys CM, Ostlie DJ, Maxson RT, Ponsky T, Tuggle DW, Eubanks JW, 3rd *et al*: Prospective validation of the shock index pediatric-adjusted (SIPA) in blunt liver and spleen trauma: An ATOMAC+ study. *J Pediatr Surg* 2017, 52(2):340-344.
11. Nordin A, Coleman A, Shi JX, Wheeler K, Xiang H, Acker S, Bensard D, Kenney B: Validation of the age-adjusted shock index using pediatric trauma quality improvement program data. *Journal of Pediatric Surgery* 2018, 53(1):130-135.
12. Vandewalle RJ, Peceny JK, Dolejs SC, Raymond JL, Rouse TM: Trends in pediatric adjusted shock index predict morbidity and mortality in children with severe blunt injuries. *Journal of Pediatric Surgery* 2018, 53(2):362-366.

	SIPA Elevated at Arrival (n=95)	SIPA Not Elevated at Arrival (n=406)	p-value
Age (years: mean, [standard deviation])	9.9 [3.3]	9.7 [3.6]	0.486
Female (n, [%])	44 [46.3%]	131 [32.2%]	**0.009**
ISS (median, [IQR])	10 [10-14]	10 [10-13]	0.433
Head AIS (median, [IQR])	0 [0-3]	2 [0-3]	**0.003**
Transfusion in first 24h of arrival (n, [%])	8 [8.4%]	8 [2.0%]	**0.001**
VAP (n, [%])	2 [2.1%]	4 [1.0%]	0.365
UTI (n, [%])	2 [2.1%]	3 [0.7%]	0.227
SSI (n, [%])	1 [1.1%]	0 [0%]	**0.038**
Bacteremia (n, [%])	0 [0%]	0 [0%]	N/A
Any (n, [%])	4 [4.2%]	7 [1.7%]	0.135
LOS (median, [IQR])	2.6 [1.8-4.9]	2.0 [1.4-3.6]	**0.010**
ICU LOS (median, [IQR])	0 [0-0.25]	0 [0]	0.408
Total days on ventilator (days: mean, [standard deviation])	0.4 [1.2]	0.2 [1.8]	**0.003**
Discharge to rehab (n, [%])	3 [3.2%]	3 [3.2%]	0.465
Death prior to discharge (n, [%])	0 [0%]	0 [0%]	N/A
Death within 48h of admission (n, [%])	0 [0%]	0 [0%]	N/A

Table 1. Patient Demographics and Outcome Variables (significant variables in bold)

	SIPA Elevated at Arrival (n=95)					
	Normalized by 12 hours (n=59)	Normalized by 24 hours (n=15)	Normalized by 36 hours (n=10)	Normalized by 48 hours (n=4)	Normalized beyond 48 hours (n=7)	p-value
LOS (days: median [IQR])	2.2 [1.7-4.35]	2.6 [1.5-3.9]	2.5 [1.9-4.3]	3.0 [2.0-4.6]	10.0 [7.0-15.5]	**0.020**
SSI (n, [%])	0 [0%]	0 [0%]	0 [0%]	0 [0%]	1 [14.3%]	**0.013**
Any Infection (n, [%])	1 [1.7%]	0 [0%]	0 [0%]	0 [0%]	3 [42.9%]	**<0.001**

Table 2. Analysis of All Patients with Elevated SIPA at Arrival (significant variables in bold)

	SIPA Not Elevated at Arrival (n=406)			
	SIPA Always Normal (n=305)	SIPA Elevated at 12 hours (n=60)	SIPA Elevated at 24 hours (n=12)	p-value
LOS (days: median [IQR])	2.0 [1.0-3.0]	2.6 [1.6-4.2]	3.4 [2.0-4.5]	**<0.001**
Transfusion in first 24 hours	3 [1.0%]	1 [1.7%]	2 [16.7%]	**<0.001**
UTI (n, [%])	0 [0%]	3 [5.0%]	0 [0%]	**0.002**
Any Infection (n, [%])	3 [1.0%]	4 [6.7%]	0 [0%]	**0.035**
Discharge to Rehab (n, [%])	3 [1.0%]	3 [5.0%]	0 [0%]	0.078

Table 3. Analysis of All Patients with Normal SIPA at Arrival (significant variables in bold)

	Head AIS = 0 & SIPA Elevated at Arrival (n=54)					
	Normalized by 12 hours (n=7)	Normalized by 24 hours (n=30)	Normalized by 36 hours (n=9)	Normalized by 48 hours (n=4)	Normalized beyond 48 hours (n=4)	p-value
LOS (days: median [IQR])	2.0 [1.7-3.0]	2.6 [1.9-3.0]	3.4 [2.0-5.0]	3.0 [2.0-4.6]	9.5 [8.0-10.0]	**0.003**
Any Infection (n, [%])	0 [0%]	0 [0%]	0 [0%]	0 [0%]	3 [75.0%]	**<0.001**

Table 4. Analysis of Patients with Head AIS = 0 and Elevated SIPA at Arrival (significant variables in bold)

	Head AIS = 0 & SIPA Not Elevated at Arrival (n=167)			
	SIPA Always Normal (n=114)	SIPA Elevated at 12 hours (n=30)	SIPA Elevated at 24 hours (n=5)	p-value
LOS (days: median [IQR])	2.0 [1.5-3.0]	3.0 [2.0-4.0]	4.0 [2.5-5.0]	**0.001**
Transfusion in first 24 hours	1 [0.9%]	0 [0%]	1 [20.0%]	**<0.001**

Table 5. Analysis of Patients with Head AIS = 0 and Normal SIPA at Arrival (significant variables in bold)

	Head AIS > 0 & SIPA Elevated at Arrival (n=41)					
	Normalized by 12 hours (n=29)	Normalized by 24 hours (n=6)	Normalized by 36 hours (n=6)	Normalized by 48 hours (n=0)	Normalized beyond 48 hours (n=0)	p-value
LOS (days: median [IQR])	2.7 [1.7-6.0]	4.5 [1.8-10.1]	2.5 [1.8-3.0]	N/A	N/A	0.828
Any Infection (n, [%])	1 [3.4%]	0 [0%]	0 [0%]	N/A	N/A	0.809

Table 6. Analysis of Patients with Head AIS > 0 and Elevated SIPA at Arrival (significant variables in bold)

	Head AIS > 0 & SIPA Not Elevated at Arrival (n=239)			
	SIPA Always Normal (n=191)	SIPA Elevated at 12 hours (n=30)	SIPA Elevated at 24 hours (n=7)	p-value
LOS (days: median [IQR])	1.9 [1.0-3.0]	2.1 [1.0-4.4]	3.0 [2.0-7.4]	**0.014**
Days on Ventilator (days: median [IQR])	0 [0]	0 [0]	0 [0-1.0]	**<0.001**
Transfusion in first 24 hours	2 [1.0%]	1 [3.3%]	1 [14.3%]	0.093
UTI (n, [%])	0 [0%]	2 [6.7%]	0 [0%]	**0.007**
Any Infection (n, [%])	2 [1.0%]	3 [10.0%]	0 [0%]	**0.031**
Discharge to Rehab (n, [%])	3 [1.6%]	3 [10.0%]	0 [0%]	**0.017**

Table 7. Analysis of Patients with Head AIS > 0 and Normal SIPA at Arrival (significant variables in bold)

	Head AIS >0 (n=280)	Head AIS =0 (n=221)	p-value
Age (years: mean, [standard deviation])	9.7 [3.7]	10.0 [3.4]	0.072
Female (n, [%])	89 [31.7%]	86 [38.9%]	0.109
ISS (mean, [standard deviation])	11.3 [1.7]	10.8 [1.5]	**<0.001**
Head AIS (median, [IQR])	3 [3-3]	0 [0]	N/A
Elevated SIPA at Arrival	41 [14.6%]	54 [24.4%]	**0.005**
Transfusion in first 24h of arrival (n, [%])	9 [3.2%]	7 [3.2%]	1.000
VAP (n, [%])	4 [1.4%]	2 [0.9%]	0.699
UTI (n, [%])	3 [1.1%]	2 [0.9%]	0.855
SSI (n, [%])	0 [0%]	1 [0.5%]	0.259
Bacteremia (n, [%])	0 [0%]	0 [0%]	N/A
Any (n, [%])	6 [2.1%]	5 [2.3%]	0.923
LOS (days: mean, [standard deviation])	3.8 [6.9]	3.5 [3.7]	**0.012**
ICU LOS (days: mean, [standard deviation])	1 [3.1]	0.3 [1.0]	**<0.001**
Total days on ventilator (days: mean, [standard deviation])	0.4 [2.2]	0.1 [0.6]	**<0.001**
Discharge to rehab (n, [%])	10 [3.6%]	1 [0.5	0.465
Death prior to discharge (n, [%])	0 [0%]	0 [0%]	N/A
Death within 48h of admission (n, [%])	0 [0%]	0 [0%]	N/A

Table 8. Comparison of all patients with and without a head injury (significant variables in bold)

	Head AIS >0 & Elevated SIPA at Arrival (n=41)	Head AIS >0 & Normal SIPA at Arrival (n=240)	p-value
Age (years: mean, [standard deviation])	9.5 [3.4]	9.5 [3.7]	0.921
Female (n, [%])	15 [36.6%]	74 [30.8%]	0.464
ISS (median, [IQR])	11 [10-14]	10 [10-13]	0.196
Head AIS (median, [IQR])	3 [3-3]	3 [3-3]	0.325
Transfusion in first 24h of arrival (n, [%])	5 [12.2%]	4 [1.7%]	**<0.001**
VAP (n, [%])	1 [2.4%]	3 [1.3%]	0.553
UTI (n, [%])	1 [2.4%]	2 [0.8%]	0.355
SSI (n, [%])	0 [0%]	0 [0%]	N/A
Bacteremia (n, [%])	0 [0%]	0 [0%]	N/A
Any (n, [%])	1 [2.4%]	5 [2.1%]	0.884
LOS (days: median, [IQR])	2.8 [1.7-5]	2 [1.0-3.3]	**0.025**
ICU LOS (days: median, [IQR])	0 [0-2]	0 [0-1]	0.072
Total days on ventilator (days: mean, [standard deviation])	0.6 [1.6]	0.3 [2.3]	**<0.001**
Discharge to rehab (n, [%])	3 [7.3%]	7 [2.9%]	0.148
Death prior to discharge (n, [%])	0 [0%]	0 [0%]	N/A
Death within 48h of admission (n, [%])	0 [0%]	0 [0%]	N/A

Table 9. Comparison of all patients with head injuries with and without an elevated SIPA at arrival (significant variables in bold)